10-Gbit/s Wireless Link Using 120-GHz-Band MMIC Technologies

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Abstract— The need for a multi-gigabit-class wireless link is increasing. In this paper, a 10-Gbit/s wireless link system that uses InP high-electron-mobility-transistor MMICs in the 120-GHz band is described. The two types of system we developed are shown. One is based on photonics, and the other is all-electronics. Finally, transmission characteristics are discussed.

I. INTRODUCTION

A multi-gigabit-class wireless link is attracting a great deal of interest as a way of catching up with the expanding broadband fiber-optic networks. One promising solution to achieve a gigabit-class wireless link is to use millimeter-waves (MMWs) for the carrier frequency. The 60-GHz band is particularly stipulated as a license-free spectrum and has been the topic of much research and development [1]. On the other hand, some companies have already developed a wireless link system that achieves a 1.5-Gbit/s data rate by using either 71–76 or 81–86 GHz [2, 3]. However, no wireless link using these bands has achieved a 10-Gbit/s data transmission. As the data rate depends on the carrier frequency, we believe that the fastest and most certain way of building a 10-Gbit/s wireless link would be to exploit undeveloped frequencies above 100 GHz.

Our first technology demonstrator was based on a transmitter that uses photonic techniques for generating and modulating 120-GHz-band signals [4]. The received MMW signal is amplified and demodulated with a receiver module using a receiver InP HEMT MMIC. We later developed MMICs (Tx/Rx) and their integrated modules for all-electronic transmitters as well as receivers using InP-HEMT devices [5]. In this paper, we present two types of system for last-one-mile wireless link applications.

II. APPLICATIONS OF 10-GBIT/S WIRELESS LINKS

Possible applications of 10-Gbit/s wireless links are shown in Fig. 1. One application is as the fixed wireless access (FWA) for a 10-Gigabit Ethernet (10GbE) or OC-192. Installing fiber networks across rivers or trunk roads is difficult because of the necessary construction work and complications in obtaining authorization. An FWA system, however, is easier and cheaper to install. The other application is for temporary multi-gigabit access because it can be set up quickly and inexpensively. For example, it can be used in a disaster-recovery plan for emergencies, if fiber networks fail in a disaster. Furthermore, it can transmit the huge volume of data needed for moving pictures, such as digital cinema (which uses 3–7 Gbit/s), or high-definition real-time movies for remote medical treatment.

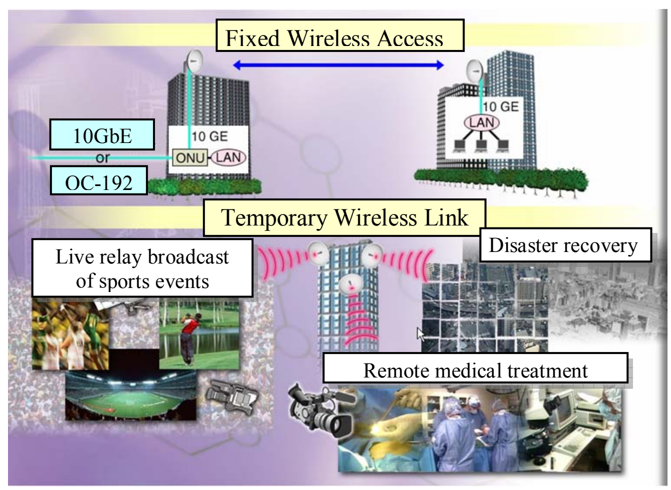

Figure 1. Possible applications of 10-Gbit/s wireless link.

The most promising application for a 10-Gbit/s wireless link is multiplexed wireless transmission of uncompressed high-definition television (HDTV) signals. For wireless transmission of broadcast materials, a field pickup unit (FPU) is commonly used. The data rate of state-of-the-art FPUs is insufficient for transmitting uncompressed HDTV signals. Therefore, the FPUs must compress the signals. This compression causes a time delay, which makes editing programs or switching cameras during live broadcasts difficult.

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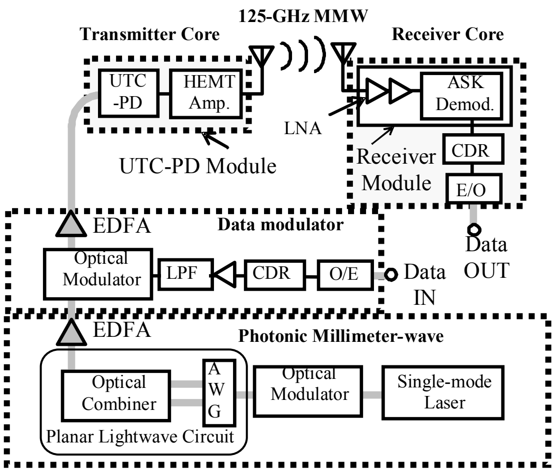
III. 120-GHz-Band Wireless Link Technologies

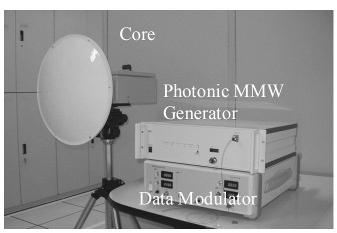
3.1 MMW link system using photonic-based signal generation technologies

State-of-the-art yet practical photonic components are advantageous for constructing over-100-GHz MMW systems because they have a larger bandwidth than electronic ones. A schematic of our wireless-link system using photonic-based MMW signal generation technologies is shown in Fig. 2.

The transmitter is composed of a low-phase-noise photonic MMW generator and a uni-traveling carrier photodiode (UTC-PD) module. The output of the single-mode laser in



(a) Schematics of system



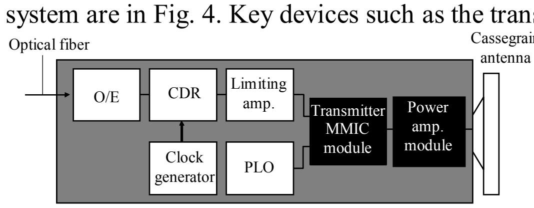
(b) Photograph of transmitter

Figure 2. 120-GHz-band wireless link system using photonic technologies

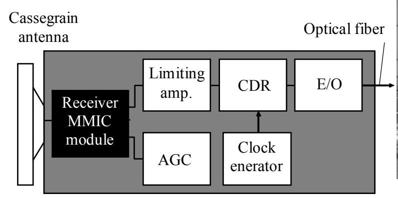
the photonic MMW generator is modulated at a 62.5-GHz frequency with an optical intensity modulator. The modulated optical signals are fed into an arrayed waveguide grating (AWG), and two output channels with a 125-GHz interval are connected to a 3-dB combiner. As a result, an optical subcarrier signal that contains two modes with a 125-GHz frequency interval is generated. The subcarrier signal is amplified by an erbium doped fiber amplifier (EDFA) and is modulated by data signals. The modulated optical signal is amplified by the second EDFA and input into the UTC-PD module. The UTC-PD is a very fast and high-power photodiode, and its output power exceeds 10 dBm at a 120-GHz frequency. The generated MMW signal is transmitted from a high-gain antenna. The received MMW signal is amplified and demodulated with a receiver module using a receiver MMIC. A photograph of the transmitter is in Fig. 2(b). We obtained experimental radio-station licenses from the Japanese Ministry of Internal Affairs and Communications in July 2004 and August 2005. These are the first licenses for an experimental radio station that uses a carrier frequency of over 100 GHz. We carried out an outdoor transmission experiment at data rates of 10.3125 Gbit/s over a distance of about 300 m and obtained a bit error rate (BER) of below 10^{-12} at a received power of -30.2 dBm.

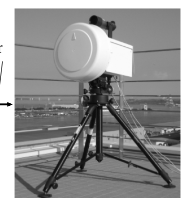
3.2 MMW link system using all-electronic technologies

Block diagrams of our newly developed wireless link system are in Fig. 4. Key devices such as the transmitter and



(a) Transmitter





(b) Receiver (c) Photograph

Figure 3. 120-GHz-band wireless link system using all-electronic technologies.

receiver ICs and power amplifier IC are packaged into compact modules with a waveguide interface. The transmitter module multiplies a 15.625-GHz CW signal from a phase locked oscillator (PLO) to 125 GHz. The ASK modulator modulates the 125-GHz MMW signal with a 10-Gbit/s data signal and then amplifies it to 1 mW. The output of the Tx module is input into the PA module, which amplifies the MMW signals to 10 mW. The I/O of the transmitter and receiver units is compatible with optical fiber network standards, such as 10 GbE and OC-192.

A photograph of the transmitter is in Fig. 3(c). The transmitter and receiver units with high-gain (>50 dBi) Cassegrain antennas are enclosed in weather-proof housing, and battery operation is possible, in particular during use as FPUs in TV broadcasting applications. The diameter of the radome is about 50 cm .

Compared to a photonic-based transmitter, the all-electronic system is compact and its total energy consumption is lower. We obtained an experimental radio-station license for this system in 2007.

We conducted a transmission experiment using a BER tester. The error-free condition, i.e., BER < 10^{-12}, was obtained at a minimum received power of -36 dBm for a 10.3125-Gbit/s data rate. We also succeeded in outdoor error-free transmission at a distance of 800 m between the roofs of two buildings over a few hours without alignment of the directions of both transmitter and receiver antennas [6]. The maximum transmission distance is estimated to be about 2 km in fair conditions. The fluctuation of received power and bit errors for 4 hours is shown in Fig. 5. No errors occurred during the experiment, and the fluctuation of the receiver power was about 1 dB. These results indicate that the 120-GHz-band wireless link is stable in cases where the transmission distance is about 800 m.

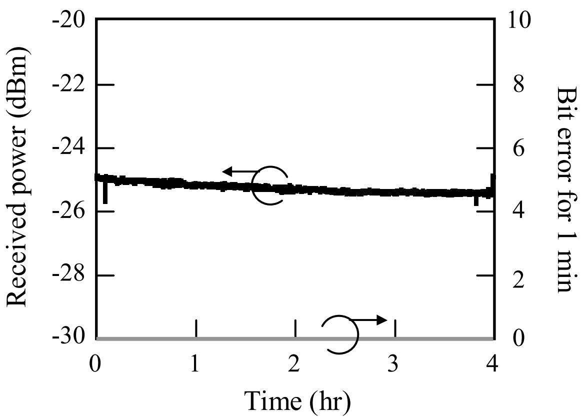


Figure 5. Fluctuation of received power and bit error of 120-GHz-band wireless link (800 m).

IV. JOINT EXPERIMENT WITH TV STATION

One of the most attractive applications of the 120-GHz-band wireless link is multiplexed wireless transmission of uncompressed HD-SDI signals. We are now conducting joint experiments with Japanese TV stations to promote the use of these frequency bands and to investigate the possibility of this wireless technology for producing TV programs. To multiply uncompressed HD-SDI signals, we have developed a multiplex system. The system consists of an i-Visto gateway [7], which can convert two HD-SDI video streams to IP packets and multiplex these packets via a 10GbE network interface, and a 10GbE switch, which multiplexes the packets from three sets of i-Visto gateway. Then, to combine the multiplex system and the 120-GHz-band wireless station, 6ch-HD-SDI signals are wirelessly transmitted. We demonstrated the systems at InterBee 2005 in Japan, IBC2007 in Netherlands, NAB2007 in USA, and BIRTV2007 in China.

V. CONCLUSIONS

We discussed the demonstration of 10-Gbit/s data transmission over a 120-GHz-band wireless link that incorporates both photonic and all-electronic technologies. The maximum transmission distance of both systems was estimated to be 2 km. Over-100-GHz MMW technologies should lead to new broadband applications, such as transmitting multiplexed uncompressed HDTV data. As for wireless transmission of broadcast materials, a higher bit rate will be needed in the near future because Super Hi-Vision, which is being developed for the next generation TV standard, requires a 24-Gbit/s data rate. We are now investigating various technologies, such as multi-value modulation methods, to expand the transmission distance and increase the data rate.

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